DOT/FAA/AR-95/51

Office of Aviation Research
Washington, D.C. 20591

Nondestructive Inspection of Piper PA-25 Forward Spar Fuselage Attachment Fitting

September 1995

Final Report

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U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-95/51		

4. Title and Subtitle NONDESTRUCTIVE INSPECTION OF PIPER PA-25 FORWARD SPAR FUSELAGE ATTACHMENT FITTING	5. Report Date September 1995
	6. Performing Organization Code
7. Author(s) David G. Moore	8. Performing Organization Report No.
9. Performing Organization Name and Address Sandia National Laboratories Aging Aircraft NDI Validation Center Albuquerque, New Mexico 87185	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTFA-03-95-X-90002
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, D.C. 20591	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code AAR-430

15. Supplementary Notes

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16. Abstract

The Federal Aviation Administration's (FAA's) Aging Aircraft NDI Validation Center (AANC) at Sandia National Laboratories applied two nondestructive inspection (NDI) techniques to inspect a forward spar fuselage attachment fitting of a Piper PA-25 aircraft. The NDI techniques used were based on radiography and ultrasonic testing methods. Each of these techniques did reveal material thinning in the attachment fitting samples cut from the PA-25 aircraft. Efforts to detect cracks in the attachment fitting using NDI techniques proved unreliable due to the geometry constraints and were therefore abandoned.

Based on the results of these experiments, an ultrasonic test procedure was subsequently developed for identifying the material thinning and is appendixed to this report. This procedure has since been incorporated by the FAA into a revision of Airworthiness Directive 93-21-12.

17. Key Words	18. Distribution Statement
Piper PA-25, corrosion, wing spar attachment, nondestructive inspection (NDI), aging aircraft, ultrasonics, radiography	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	24	

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EXECUTIVE SUMMARY

The Federal Aviation Administration's (FAA's) Aging Aircraft NDI Validation Center (AANC) at Sandia National Laboratories applied two nondestructive inspection (NDI) techniques for the inspection of a Piper PA-25 forward spar fuselage attachment fitting. A review of two PA-25 accidents revealed the susceptibility of these fittings to corrosion and corrosion induced cracking. It was believed that corrosion was a precursor to the cracking and hence this effort focused primarily on developing techniques to detect the material thinning. The nondestructive testing techniques attempted were based on radiography and ultrasonics. Each of these techniques did reveal material thinning in the attachment fitting samples from a PA-25 aircraft. Efforts to detect cracks in the attachment fitting using NDI proved unreliable due to geometry constraints and were therefore abandoned.

Based on the results of these experiments, an ultrasonic test procedure was subsequently developed for identifying the material thinning and is appendixed to this report. This procedure has since been incorporated by the FAA into a revision of Airworthiness Directive 93-21-12.

INTRODUCTION

On February 22, 1994, the Aging Aircraft Nondestructive Inspection (NDI) Validation Center (AANC)[1] was contacted by the Federal Aviation Administration (FAA) National Resource Specialist (NRS) for Nondestructive Evaluation (NDE). The FAA Atlanta Aircraft Certification Office (ACO) had requested support from the NRS concerning the development of inspection procedures to detect corrosion-induced cracking in a spar fitting on Piper PA-25 aircraft. The NRS requested the AANC to develop a low cost, portable inspection technique that could determine material thinning caused by corrosion. The detection of the material loss due to corrosion was the focus because it is believed to be a precursor to the cracking. Therefore, the procedures developed and presented in this report were evaluated and optimized for their ability to detect corrosion thinning and not for crack detection, although limited attempts to detect cracks were also studied and reported herein.

SPAR FITTING HISTORY

On May 21, 1993, an in-flight separation of the wing from a Piper PA-25 airplane occurred. The investigation of the affected airplane revealed corrosion and cracks in the forward spar fuselage attachment fittings. The forward spar fuselage attachment fitting consists of a clevis ear welded to a 4130 steel tube forward spar as illustrated in figures 1 and 2. This welded metal interface fractured at the base of the clevis ear. Extensive corrosion was found at the fracture site. Further review revealed that a strong oxidation layer between the two welded sections of the fitting assembly (washer and ear flange) had occurred over a long period of time. Figures 3 and 4 are photographs showing the corroded spar fuselage attachment. This airplane was used for agricultural crop dusting and had accumulated over 5,000 hours time in service (TIS) at the time of the accident. A similar accident had occurred previously on September 21, 1991, to an airplane with 10,000 hours TIS. These two different accidents alerted the FAA that an unsafe condition may exist on the Piper Model PA-25. The FAA also believes that airplanes utilized in agricultural environments are extremely susceptible to the above corrosion conditions.

The present nondestructive inspection techniques for the PA-25 forward spar fuselage attachment fitting are visual and dye penetrant inspections as mandated by Airworthiness Directive 93-21-12. Neither of these techniques can detect the corrosion between the clevis ear layers nor the cracks that can develop from inside the tube diameter.

NDI TECHNOLOGIES PERFORMED ON THE FORWARD SPAR ATTACHMENT FITTING

On March 4, 1994, two forward attachment spar clusters and a new Piper manufactured fitting were received from the Atlanta ACO. Sample 1 was a new, fully assembled ear fitting. To help understand the current welding process, two subassembly piece parts were also sent (figure 5). Sample 2 was a forward spar fuselage attachment cluster which had extensive pitting and surface

[1]The AANC is operated by the Department of Energy's Sandia National Laboratory in Albuquerque, NM, for the FAA Technical Center under Interagency Agreement DTFA-03-95-X-90002.

corrosion on both ear fittings. Half of one ear was removed by a bandsaw to reveal the inner layer corrosion shown in figure 6. Sample 3 was a forward spar fuselage attachment cluster used as a blind sample to develop the inspection techniques. It was not known if corrosion existed between the inner layers. Sample 3 is shown in figure 7. The AANC staff performed both radiography and ultrasonic inspections on the spar cluster assembly. Test setup, calibration, and inspection techniques are described, and findings from each technique are stated.

RADIOGRAPHY INSPECTION.

TEST SETUP. The radiographic test on the forward spar cluster (sample 2) was conducted using a standard, commercially available x-ray machine. Kodak M and AA films were assembled in a standard film cassette placed behind the spar cluster and a Pantak 320 KeV x-ray machine was used. The testing parameters were 250 KeV with a 10mA, 1.5-minute exposure with a source-to-film distance of 5 feet.

The spar cluster was radiographed using the two different film speeds (M and AA). A 0.001-inch lead foil was placed between the films to enhance the radiograph image. A 0.021-inch-thick piece of lead was also placed in front of and behind the films to eliminate some of the background noise due to scatter.

FINDINGS. The radiographs were reviewed visually. A Bausch & Lomb Measuring Magnifier was used to measure the gap between the washer/ear flange interface for corrosion and to determine if cracks could be detected in the attached tubing. A gap between the washer/ear fitting greater than the design tolerance would indicate material loss possibly due to corrosion. Film densities were also measured.

The gap between the washer and ear flange was measured to be between 0.015 to 0.025 inch for the corroded sample 2. The standard design tolerance for this gap, however, was unknown so an assessment of the corrosion thinning could not be made. Cracks in the inside tube diameter of sample 2 could not be detected. Alignment between the x-ray source and the spar cluster would be critical if this technique was used to find cracks in the tubing. For this application, radiography would not be reliable in finding cracks in the tubing without conducting several exposures at different orientations.

ULTRASONIC MATERIAL THICKNESS INSPECTION.

The ultrasonic test system used was a QUANTUM™ QFT-1 made by NDT Instruments Division, NDT Systems, Inc. This instrument was selected because it possessed both ultrasonic flaw detection capability and thickness gage (LED readout) capability. Figure 8 is a photograph of the ultrasonic system. Steel shims (manufactured by the L. S. Sarret Company) were used for the thickness calibration. The shims used were 0.020, 0.030, 0.040, 0.075, and 0.100 inch thick. These steel shims were selected because they possessed ultrasonic material velocity similar to that of the three samples. Figure 9 displays the calibration standards used for the system setup.

A contact ultrasonic test method was selected for this inspection based on the necessity that the instrument be portable. Three different contact ultrasonic transducers were evaluated. They were (1) single-element contact transducer with a thin hard-faced wear plate, (2) dual-element contact transducer with a thin hard-faced wear plate, and (3) a single-element contact transducer with a plastic delay line. The following is an evaluation of each transducer type.

TEST SETUP - SINGLE-ELEMENT CONTACT TRANSDUCER WITH A THIN HARD-FACED WEAR PLATE INSPECTION. A 10-MHz, 0.25-inch-diameter probe with a pulse-echo technique was evaluated. The probe was coupled to the 0.100-inch steel shim. The instrument range was adjusted to this maximum thickness. The detection gate delay (zero adjust) was adjusted to the first backwall echo. The instrument velocity was adjusted to display the known maximum thickness. With this setup, the thickness of the two thinnest steel shims could not be measured since the initial pulse could not be reduced enough for an accurate near surface measurement. Calibration on the thicker steel shims was successful and the results are shown in table 1. Thickness measurements were recorded for sample 1, the fully assembled ear fitting, at eight measurement locations around the test sample. Figure 10 illustrates the eight locations where ultrasonic measurements were taken on the samples. Table 2 displays the test results for the 10-MHz, single-element probe on sample 1.

The test setup was then applied on the surface corroded sample 2. The thickness of sample 2 could not be determined. The instrument sensitivity (gain) was increased and the backwall echo still could not be detected. The problems with sample 2 were due to the rough outer surface of the test sample. Figure 11 illustrates the undesirable effect of surface roughness on the distortion of ultrasonic wave propagation. This probe and technique were abandoned.

FINDINGS: The test system (probe and instrument) percent accuracy based on the 0.075-inch calibration thickness is 1.33 percent. This instrumentation error is assumed to be in the measurements on sample 1 found in table 2. A variance in measurements was not conducted on this probe because it could not perform a thickness measurement on sample 2.

TEST SETUP - DUAL-ELEMENT CONTACT TRANSDUCER WITH A THIN HARD-FACED WEAR PLATE INSPECTION. A 3.5-MHz, 0.25-inch-diameter probe with a pitch/catch technique was evaluated next. This method was selected to improve the sound penetration in sample 2 due to its rough surface and maximize the ultrasonic response from within the test material. The probe was coupled to the 0.100-inch steel shim. The instrument range was adjusted to this maximum thickness. The detection gate delay (zero adjust) was adjusted to the first backwall echo. The instrument velocity was adjusted to display the known maximum thickness. Thickness could not be determined for the thinner steel shims (0.020 - 0.040 inch). Calibration on two of the thicker steel shims was successful (0.075 and 0.100 inch). Thickness was determined for the inner surface of samples 1 and 2. The same sensitivity (instrument gain) as the steel shims was used. However, thickness measurements were not obtained for the outside dimension of samples 1 and 2. The outside dimension was thinner than the 0.075-inch steel shim and not within the calibration range. This test method was abandoned.

FINDINGS. A variance in measurements was not conducted on this probe because it could not perform an outside surface thickness measurement on samples 2 and 3.

TEST SETUP - SINGLE-ELEMENT CONTACT TRANSDUCER WITH A PLASTIC DELAY LINE. Two 15-MHz, 0.25-inch-diameter probes with a 0.375-inch plastic delay using a pulse-echo technique were evaluated. This method was selected to improve the near surface resolution of the inspection. The calibration on most of the steel shims was successful with the first transducer. Thickness measurements were recorded for all three samples. The calibration on all of the steel shims was successful with the second transducer. Thickness measurements were recorded for all three samples. The final inspection technique developed using these transducers is found in appendix A.

FINDINGS. The percent accuracy based on the 0.075-inch calibration thickness for both ultrasonic probes was 2.66 percent (+0.002 inch). This instrumentation error was assumed to be in the measurements on all three test samples. Table 3 displays the calibration range used on the first ultrasonic probe and the eight measurement locations. The test setup was calibrated for the range of 0.040-0.100 inch. Tables 4 through 6 display the inspection results for the first probe on test samples 1, 2, and 3.

Table 7 displays the calibration range used on the second ultrasonic probe. The measurement locations were similar to the previous test; however, to more fully assess sources of variability in the possible variance of the thickness measurements, a second inspector also took measurements with the second probe. Tables 8 through 10 display the inspection results for the second probe for the two inspectors.

An attempt to establish a thickness measurement (confidence level) outside the experimental error was conducted. Table 11 displays the thickness variation between two different inspectors and two different delay line transducers (probes). The highest variability was found between samples 2 and 3. The maximum variability was + 0.008 inch at the same measurement location. Table 12 displays the thickness variation between the two inspectors and the same probe. The highest variability was found between samples 2 and 3. The maximum variability for sample 2 was + 0.008 inch and the maximum variability for sample 3 was + 0.007 inch.

The variability between probes and operators is due mainly to the signal amplitude caused by surface roughness and the care the operator takes to maximize the return echo. The gate threshold that detects the material thickness can trigger on the first or second positive half cycle of the ultrasonic backwall signal. The difference between the first and second positive half cycle is calculated in steel to be 0.008 inch for a 15-MHz probe. It is believed that the variability between the two different probes and two different inspectors was caused by the signal amplitude of the first positive half cycle either triggering or not triggering the thickness measuring logic circuits of the instrument. Probe manipulation and scanning technique affect the height of the return echo. The return echo height determines which cycle the trigger gate detects. The specification of a material thinning requirement to detect inner layer corrosion should accommodate a thickness variability of 0.008 inch in addition to the calibration error.

CONCLUSIONS

Based on the experiments conducted, the single-element transducer with a plastic delay line was the optimum test method for detecting material thinning in the sample PA-25 spar attachment fittings. This method can be employed in the field with a percent calibration accuracy based on the 0.075-inch calibration shim of 2.6 percent. A key to developing a reliable ultrasonic inspection method is to overcome the surface roughness that may be present.

At the time of publishing this report, the single-element ultrasonic technique with the plastic delay line has been incorporated by the FAA into a revision of AD 93-21-12.

TABLE 1. CALIBRATION THICKNESS MEASUREMENTS FOR THE SINGLE-ELEMENT 10-MHZ TRANSDUCER WITH THE HARD-FACED WEAR PLATE

Calibration Thickness (inches)	Ultrasonic Measurement (inches)	Percent Accuracy Based on the 0.075 Inch Reading
0.020	***	$\frac{(0.075 - 0.074)}{(0.075)} * 100 = 1.33\%$
0.030	***	
0.040	0.039	
0.075	0.074	
0.100	0.100	

*** Ultrasonic thickness measurements could not be made for these shims. The instrument could not reduce the initial pulse enough for an accurate near surface measurement.

TABLE 2. THICKNESS MEASUREMENTS FOR THE SINGLE-ELEMENT 10-MHZ TRANSDUCER WITH THE HARD-FACED WEAR PLATE ON SAMPLE 1

Measurement	Outside		Inside	
Location	Thickness (inches)	Gain (dB)	Thickness (inches)	Gain (dB)
1	0.059	58	0.095	58
2	0.059	58	0.095	58
3	0.059	58	0.095	58
4	0.059	58	0.095	58
5	0.059	58	0.095	58
6	0.059	58	0.100	58
7	0.059	58	0.100	58
8	0.059	58	0.100	58

TABLE 3. CALIBRATION THICKNESS MEASUREMENTS FOR THE FIRST 15-MHZ DELAY LINE PROBE AND MEASUREMENT LOCATIONS FOR SAMPLES 1, 2, AND 3.

Calibration Thickness (inches)	Ultrasonic Measurement (inches)	Percent Accuracy Based on 0.075 Reading
		$\frac{(0.077 - 0.075)}{(0.075)} * 100 = 2.66\%$
0.040	0.040	
0.050 *	0.049	* An additional thickness block was added to the calibration standards.
0.075	0.077	
0.100	0.100	

TABLE 4. THICKNESS MEASUREMENTS FOR THE FIRST 15-MHZ DELAY LINE PROBE ON SAMPLE 1 WHERE NO CORROSION WAS PRESENT.

Measurement Location	Outside Thickness (inches)	Gain (dB)	Inside Thickness (inches)	Gain (dB)
1	0.063	63	0.100	63
2	0.063	63	0.100	63
3	0.063	63	0.102	63
4	0.063	63	0.100	63
5	0.063	63	0.100	63
6	0.063	63	0.100	63
7	0.063	63	0.100	63
8	0.063	63	0.100	63

TABLE 5. THICKNESS MEASUREMENTS FOR THE FIRST 15-MHZ DELAY LINE PROBE ON SAMPLE 2 WHERE CORROSION WAS INDICATED IN THE OUTSIDE AND INSIDE MEASUREMENTS.

Measurement Location	Outside Thickness (inches)	Gain (dB)	Inside Thickness (inches)	Gain (dB)
1	0.063	62	0.095	73
2	0.063	62	0.095	73
3	0.063	62	0.100	73
4	0.063	62	0.100	67
5	0.058	66	0.100	67
6	0.058	66	0.100	67
7	0.058	73	0.100	74
8	0.063	66	0.095	74

TABLE 6. THICKNESS MEASUREMENTS FOR THE FIRST 15-MHZ DELAY LINE PROBE ON SAMPLE 3 WHERE CORROSION WAS NOT INDICATED ON THE OUTSIDE MEASUREMENTS AND UNKNOWN FOR THE INSIDE MEASUREMENTS.

Measurement Location	Outside Thickness (inches)	Gain (dB)	Inside Thickness (inches)	Gain (dB)
1	0.068	63	0.100	63
2	0.068	63	0.100	63
3	0.068	63	0.095	63
4	0.068	63	0.095	63
5	0.068	63	0.095	63
6	0.068	63	0.095	63
7	0.068	63	0.095	63
8	0.068	63	0.100	63

TABLE 7. CALIBRATION MEASUREMENTS FOR THE SECOND 15-MHZ DELAY LINE PROBE.

Calibration Thickness (inches)	Ultrasonic Measurement (inches)
0.020	0.039*
0.030	0.032
0.040	0.040
0.075	0.077
0.100	0.100

Percent Accuracy Based on 0.075 Reading

$$\frac{(0.077-0.075)}{(0.075)} * 100 = 2.66\%$$

* The gate measured the second multiple of the backwall echo. This measurement must be divided by two.

TABLE 8. THICKNESS MEASUREMENTS FOR THE SECOND 15-MHZ DELAY LINE PROBE ON SAMPLE 1 WITH TWO DIFFERENT INSPECTORS (1 AND 2) WHERE NO CORROSION WAS PRESENT.

Measurement	Outside (1)		Inside (1)		Outside (2)		Inside (2)	
	Thickness	Gain	Thickness	Gain	Thickness	Gain	Thickness	Gain
Location	(inches)	(dB)	(inches)	(dB)	(inches)	(dB)	(inches)	(dB)
1	0.065	64	0.097	64	0.063	64	0.100	64
2	0.065	64	0.097	64	0.063	64	0.100	64
3	0.065	64	0.097	64	0.063	64	0.100	64
4	0.065	64	0.097	64	0.063	64	0.100	64
5	0.065	64	0.097	64	0.063	64	0.100	64
6	0.065	64	0.097	64	0.063	64	0.100	64
7	0.065	64	0.097	64	0.063	64	0.100	64
8	0.065	64	0.097	64	0.063	64	0.100	64

TABLE 9. THICKNESS MEASUREMENTS FOR THE SECOND 15-MHZ DELAY LINE PROBE ON SAMPLE 2 WITH TWO DIFFERENT INSPECTORS (1 AND 2) WHERE CORROSION WAS INDICATED IN THE OUTSIDE AND INSIDE MEASUREMENTS.

Measurement	Outside (1)		Inside (1)		Outside (2)		Inside (2)	
	Thickness	Gain	Thickness	Gain	Thickness	Gain	Thickness	Gain
Location	(inches)	(dB)	(inches)	(dB)	(inches)	(dB)	(inches)	(dB)
1	0.061	64	0.092	69	0.063	64	0.100	64
2	0.061	64	0.092	69	0.063	64	0.100	64
3	0.056	64	0.092	69	0.063	64	0.100	64
4	0.056	64	0.097	69	0.063	64	0.100	68
5	0.056	64	0.097	69	0.058	64	0.100	70
6	0.056	66	0.097	69	0.058	64	0.100	68
7	0.056	70	0.097	69	0.064	64	0.100	64
8	0.061	64	0.097	69	0.063	64	0.100	64

TABLE 10. THICKNESS MEASUREMENTS FOR THE SECOND 15-MHZ DELAY LINE PROBE ON SAMPLE 3 WITH TWO DIFFERENT INSPECTORS (1 AND 2) WHERE CORROSION WAS NOT INDICATED ON THE OUTSIDE MEASUREMENTS AND UNKNOWN FOR THE INSIDE MEASUREMENTS.

Measurement Location	Outside (1) Thickness (inches)	Outside (1) Gain (dB)	Inside (1) Thickness (inches)	Inside (1) Gain (dB)	Outside (2) Thickness (inches)	Outside (2) Gain (dB)	Inside (2) Thickness (inches)	Inside (2) Gain (dB)
1	0.065	64	0.092	64	0.068	64	0.095	64
2	0.065	64	0.092	64	0.068	64	0.095	64
3	0.065	64	0.094	64	0.068	64	0.095	64
4	0.065	64	0.094	64	0.068	64	0.095	64
5	0.065	64	0.092	64	0.068	64	0.095	64
6	0.065	64	0.097	64	0.068	64	0.095	64
7	0.066	67	0.092	64	0.068	64	0.095	64
8	0.061	64	0.092	64	0.068	64	0.095	64

TABLE 11. THICKNESS VARIATION BETWEEN THE FIRST AND SECOND 15-MHZ DELAY LINE PROBE FOR SAMPLES 1, 2, AND 3 FOR TWO DIFFERENT INSPECTORS EACH USING ONE PROBE.

Measurement	Sample 1 inches		Sample 2 inches		Sample 3 inches	
	outside	inside	outside	inside	outside	inside
1	0.002	0.003	0.002	0.003	0.003	0.008
2	0.002	0.003	0.002	0.003	0.003	0.008
3	0.002	0.005	0.007	0.008	0.003	0.001
4	0.002	0.003	0.007	0.003	0.003	0.001
5	0.002	0.003	0.002	0.003	0.003	0.003
6	0.002	0.003	0.002	0.003	0.003	0.002
7	0.002	0.003	0.002	0.003	0.002	0.003
8	0.002	0.003	0.002	0.002	0.007	0.008

TABLE 12. VARIATION BETWEEN TWO INSPECTORS ON SAMPLES 1, 2, AND 3 FOR THE SECOND PROBE ONLY.

Measurement	Sample 1 inches		Sample 2 inches		Sample 3 inches	
	outside	inside	outside	inside	outside	inside
1	0.002	0.003	0.002	0.008	0.003	0.003
2	0.002	0.003	0.002	0.008	0.003	0.003
3	0.002	0.003	0.007	0.008	0.003	0.001
4	0.002	0.003	0.007	0.003	0.003	0.001
5	0.002	0.003	0.002	0.003	0.003	0.003
6	0.002	0.003	0.002	0.003	0.003	0.002
7	0.002	0.003	0.008	0.003	0.002	0.003
8	0.002	0.003	0.002	0.003	0.007	0.003

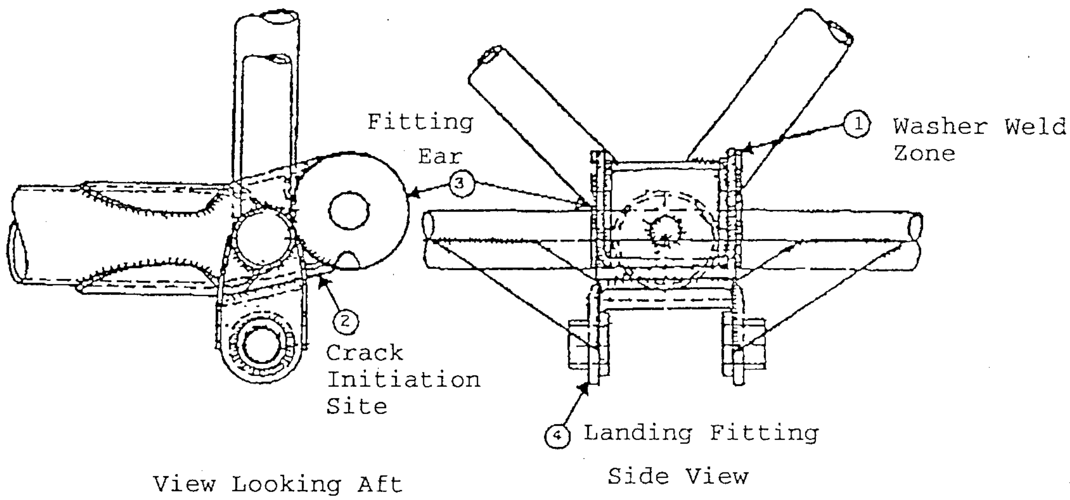


FIGURE 1. VIEW LOOKING AFT AND A SIDE VIEW OF THE SPAR ATTACHMENT FITTING FOR THE PIPER MODEL PA-25-150. FIGURE WAS TAKEN FROM AD 93-21-12.

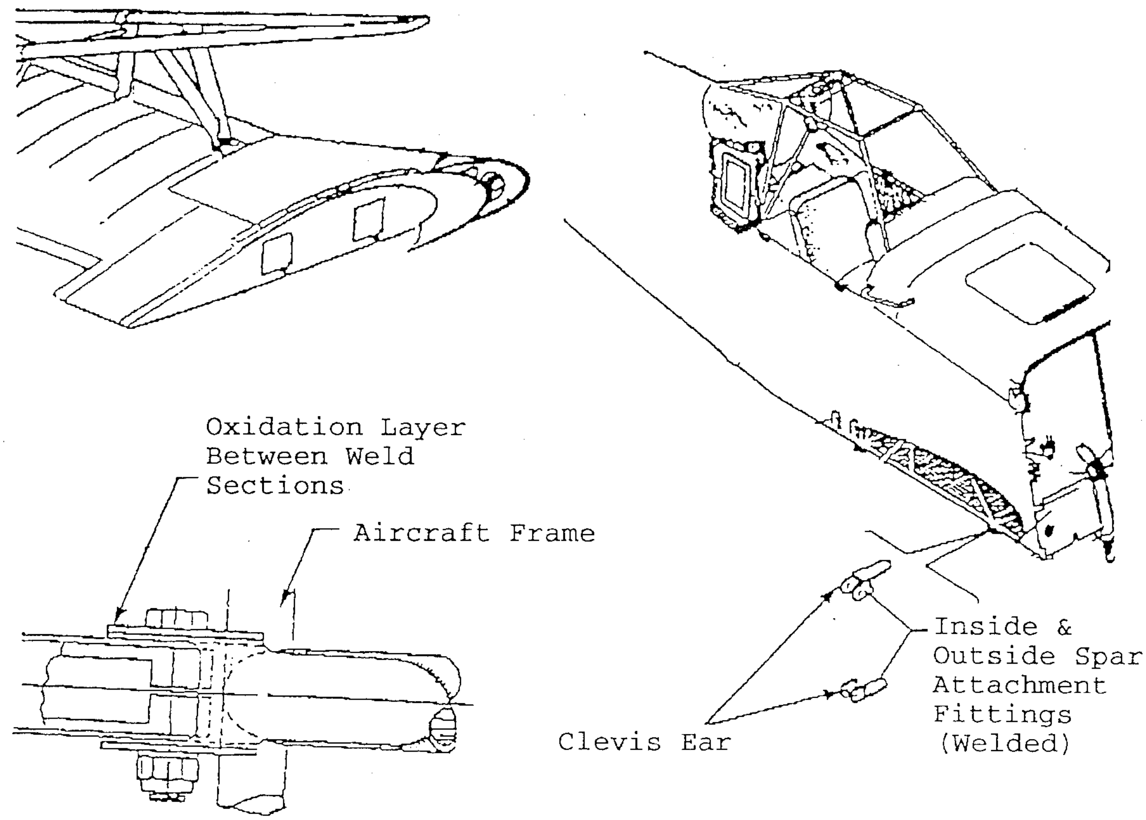


FIGURE 2. LOWER ATTACHMENT FITTING EAR AS ASSEMBLED IN THE PRESENT CONFIGURATION. FIGURE WAS TAKEN FROM AD-93-21-12.

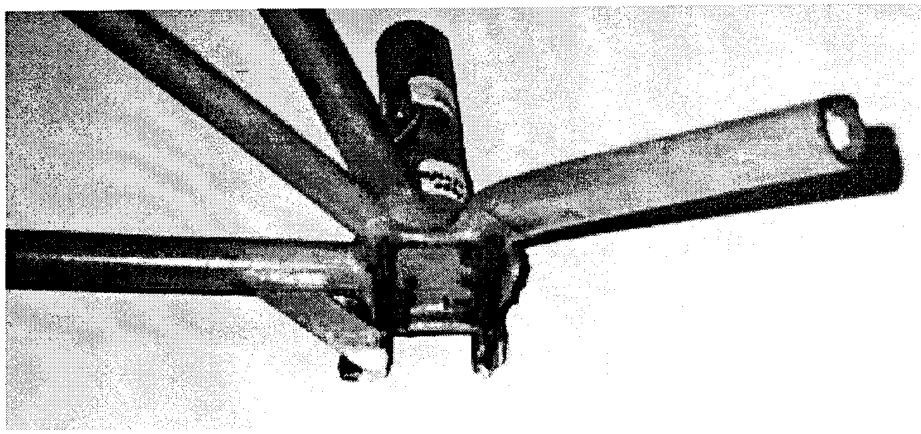


FIGURE 3. PICTURE OF THE FORWARD SPAR FUSELAGE ATTACHMENT CLUSTER CUT FROM AN ACCIDENT AIRPLANE IN ALABAMA.

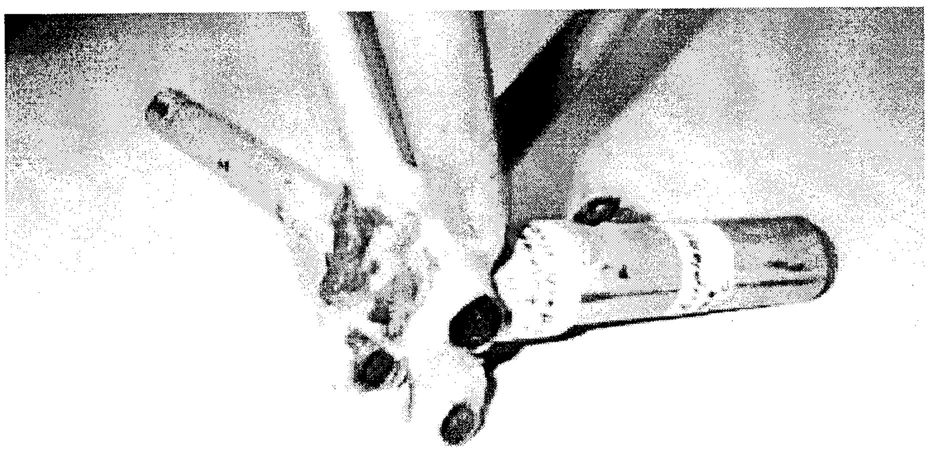


FIGURE 4. SIDE VIEW OF FIGURE 3 THAT DISPLAYS THE EXTENSIVE CORROSION OF THE FITTING EARS.

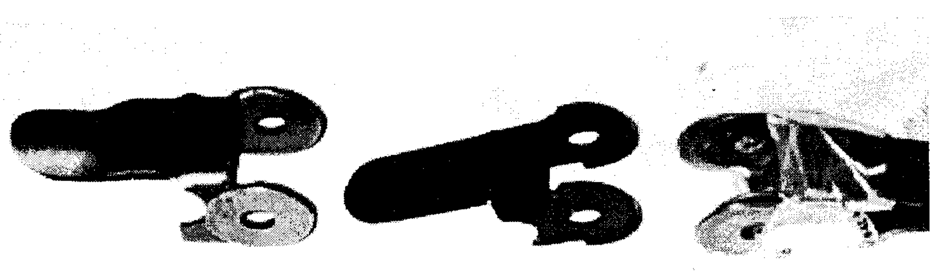


FIGURE 5. SAMPLE 1 - A NEW, FULLY ASSEMBLED EAR FITTING (FAR LEFT) AND TWO SUBASSEMBLY PARTS.

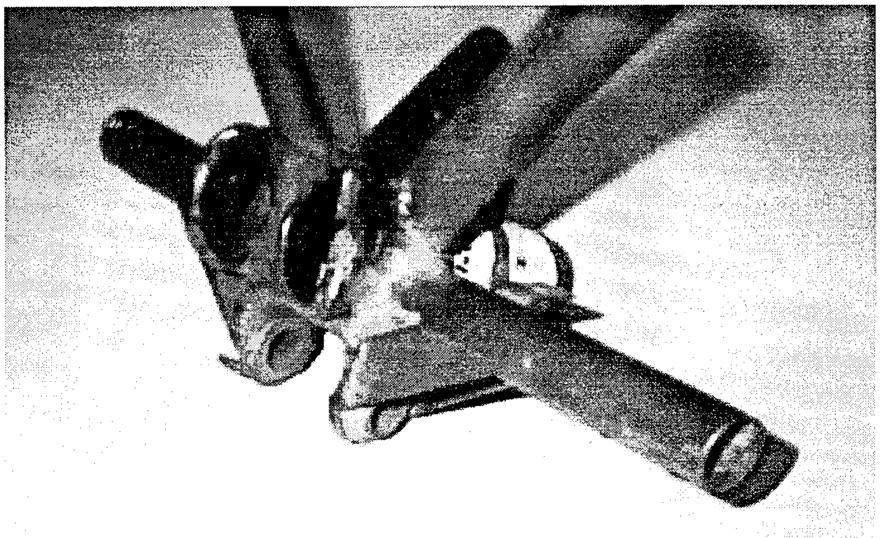


FIGURE 6. SAMPLE 2 - FORWARD SPAR FUSELAGE TUBULAR ATTACHMENT CLUSTER FROM A PA-25 AIRPLANE. NOTE: HALF OF ONE EAR WAS REMOVED BY A BAND SAW. THE DARKER AREA IS CORROSION.

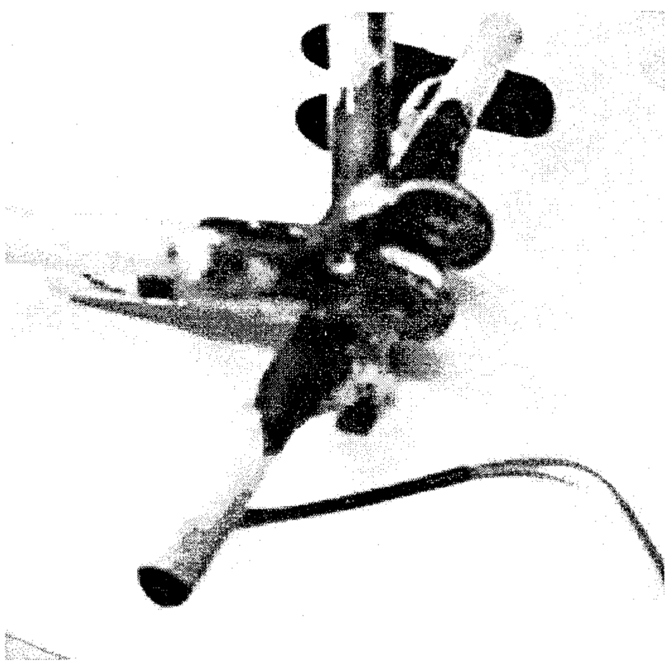


FIGURE 7. SAMPLE 3 - BLIND SAMPLE USED TO DEVELOP THE INSPECTION TECHNIQUES.

FIGURE 8. ULTRASONIC THICKNESS GAGE USED FOR THIS EXPERIMENT. THIS UNIT IS PORTABLE, AND HAS SETUP STORAGE CAPABILITY. THE UNIT ALSO HAS BOTH THICKNESS READOUT AND AN A-SCAN PRESENTATION DISPLAY.

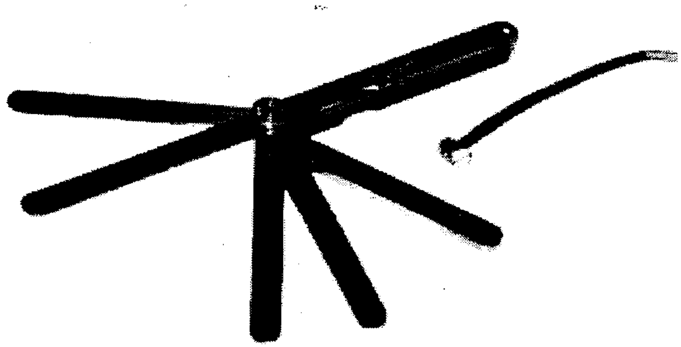
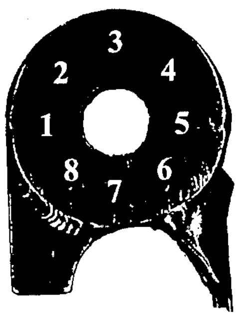
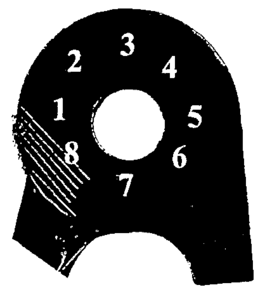


FIGURE 9. STEEL SHIMS USED FOR THE THICKNESS CALIBRATION (MANUFACTURED BY THE L.S. SARRETT CO.). THE SHIMS USED WERE 0.020, 0.030, 0.040, 0.050, 0.075, AND 0.100 INCH THICK.



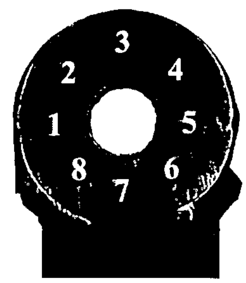
Outside surface of Piper Replacement Part



Inside surface of Piper Replacement Part

Welded area

Outside surface of Sample 2 and Sample 3 Forward Spar Cluster



Inside surface of Sample 2 and Sample 3 Forward Spar Cluster

FIGURE 10. ILLUSTRATION OF THE EIGHT ULTRASONIC MEASURMENT LOCATIONS FOR VARIOUS SAMPLES. SAMPLE 1 LOCATIONS WERE SIMILAR.

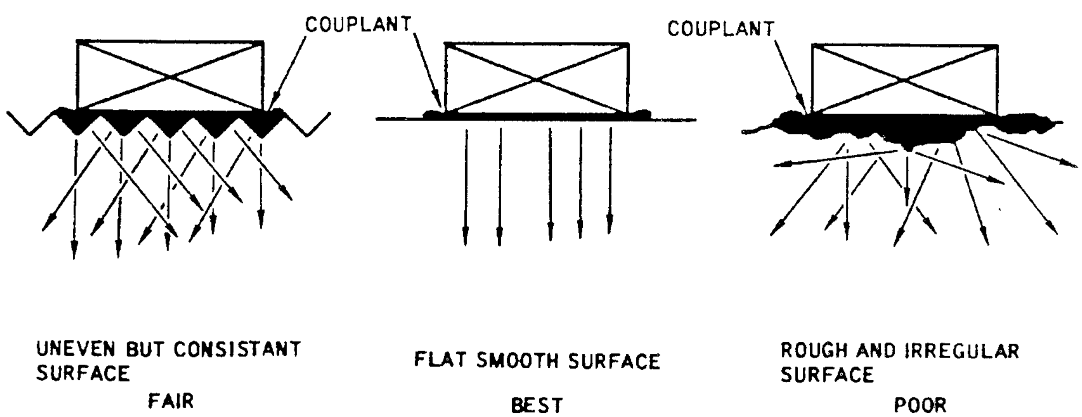


FIGURE 11. ILLUSTRATION OF THE UNDESIRABLE EFFECT OF DISTORTION OF WAVE DIRECTIVITY DUE TO THE SURFACE OF THE TEST SPECIMEN AND HOW IT CAN GREATLY AFFECT ULTRASONIC WAVE PROPAGATION.

APPENDIX A

Inspection Procedure Using a Single-Element Contact Transducer with a Plastic Delay Line

Inspection Procedure to Detect Material Thinning Caused by Corrosion for a Piper Model PA25 Forward Spar Fuselage Attachment Fitting Using a Ultrasonic Contact Transducer with a Plastic Delay Line

1. Purpose

To find and estimate material thinning of the two welded sections on the forward spar fuselage attachment fitting assembly (washer and ear flange) caused by corrosion. This inspection procedure uses a Quantum™ QFT-1 ultrasonic test instrument and a contact transducer with a plastic delay line.

Note: It is recommended that the assigned inspector using this equipment and the following procedure must be experience and well founded in the fundamentals of ultrasonic testing. Inspectors should fully possess the qualification of ultrasonic testing personnel as defined in Recommended Practice No. SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing, available from ASNT (American Society for Nondestructive Testing).

2. Equipment

A. A NDT Systems, Inc., QUANTUM™ Model QFT-1 was used. An equivalent portable combination ultrasonic flaw detector/thickness gage possessing both LED readout and A-trace can be used.

B. The ultrasonic probe used in this test setup was a Nova D11R replaceable delay line transducer with replaceable D11R-T tips. An equivalent 15-Megahertz, 0.25-inch-diameter probe with a 0.375-inch plastic delay line can be used.

C. The standard used for thickness calibration were steel shims manufactured by the L. S. Sarret Company. To ensure proper calibration, the steel shims should be free of scratches and dirt. To verify the shim thickness a zero to one inch calibrated micrometer should be used to measure the steel shims.

D. The couplant used in performing the calibration and the inspection should not be water based. Glycerin and 3-in-1 oil were used to conduct this test set-up and inspection .

3. Material Preparation

A. The forward spar fuselage attachment fitting should have bubbled or flaking paint removed. If surface pitting is found on the either side of the ear flange it should be lightly sanded. Removal of surface pits will enhance the accuracy of the inspection technique.

4. Instrument Calibration

A. Turn the instrument power on and check the battery charge status. The instrument should have at least 40% of available battery life. Select the NEW setup option. Adjust the screen brightness and contrast of the display screen for the desired environmental conditions (e.g., outside sunlight). Note: Unscrew the plastic delay line from the transducer. Add couplant (3-in-1 oil) to the base of the delay line. Then reattach the delay line.

B. Obtain steel shims with the thicknesses of 0.020, 0.030, 0.040, 0.050, 0.075, and 0.100 inch. Couple the probe to the 0.100-inch steel shim using a drop of glycerin or 3-in-1 oil. An A-trace will appear on the screen and a thickness readout will appear in the

right hand corner. The signals on the screen from left to right are the initial pulse, the delay line, front surface of the steel shim, and the backwall echo of the 0.100-inch steel shim. A thin horizontal bar should be present at the 30% full-scale screen height. This horizontal bar represents the thickness gate. The thickness gate will terminate at the delay line to steel shim interface.

C. Select the signal element transducer setting from the probe selection (PRB) menu. Adjust the gain setting to increase the backwall signal from the 0.100 steel shim to 80% (approximately 63 dB). Adjust the damping, voltage, and pulse width to obtain the maximum signal response. The values selected for this inspection were inspection were 34 ohms, 200 volts, and 30 nanoseconds. These settings will vary from probe to probe. Note: If a new setting is selected on the power-up sequence, the range setting defaults to 2.0 inches. Exit the probe selection menu.

D. Select the display (DSP) menu. Adjust the arrow keys to display all the waveforms. Select the waveform that gives the best signal display on the 0.100-inch steel shim. The value selected for the inspection was positive half-wave rectified. Select the Interface synchronization IF SYNC. This selection automatically starts the thickness gate at the leading edge of the interface echo. Exit the display menu and return to the main menu.

E. Select the thickness (THK) menu. Move the cursor to the BLOCK menu and adjust the blocking gate to three-quarters of the distance between the initial pulse and the interface echoes. This step assures a stable interface IF SYNC.

F. Select the calibration (CAL) menu. Move the cursor to the range (R) menu. Decrease the range to 0.34 inch. Several of the multiple backwall echos will disappear from the screen. The thickness readout should be present in the right hand corner. The reading should be near 0.100 inch. Move the cursor to the velocity (V) menu. Select a velocity of 0.231 in/μs. The reading should be 0.100 inch. Now couple the transducer to the thinnest steel shim. If the thickness readout does not agree with the known thickness, reposition the cursor to the zero (Z) menu. Use the arrow keys to produce the known thickness. Again check the thickest shim. If the readout does not read the correct thickness re-adjust the zero value. After this adjustment is made, record the thickness values for each of the steel shims. The calibration procedure is now complete.

5. Inspection Procedure

A. Add couplant to the outside inspection surface. To assure proper coupling to the test sample, twist the probe clockwise and counterclockwise (with a 45 degree twist) and maintain contact with the test surface. Measure and record the thickness. Repeat the above process at eight equally spaced locations around the washer.

B. Add couplant to the inside inspection surface. To assure proper coupling to the test sample twist the probe (clockwise and counterclockwise with a 45 degree twist). Measure and record the thickness. Repeat the above process at eight equally spaced locations around the ear flange.

6. Inspection Results

A. Refer to the applicable documentation for the corrosion limits.

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